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Online listening tests on sound insulation of walls – A feasibility study

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Summary

As part of the COST Action TU0901 WG 2 activities a listening test was made on the annoyance potential of airborne noise from neighbours heard through walls. 22 assessors from 11 countries rated six simulated walls with four types of neighbour noise online at the assessor's premises using the ISO/TS 15666 annoyance scale. A simple "calibration" procedure based on adjusting a speech sample to natural level for approximate calibration was used. Dose-response curves for neighbour noise, i.e. the annoyance potential of neighbour noise heard on the receiving side of the walls as function of the A-weighted levels or the loudness levels was found with high correlations between levels and annoyance. For the combination of the selected walls and noise types a high correlation was also found between the annoyance potential of the neighbour noise and the R'_w -values for the simulated walls.

1. Introduction

Subjective evaluation of sound insulation between neighbour dwellings is the main topic of COST TU0901 WG2 [1], and listening tests is a tool for performing investigations.

Noise annoyance is a complex concept that depends on many factors, among these the level and type of the noise, the persons exposed, their expectations and the context of the noise exposure. The topic of this paper is the annoyance of neighbour noise heard through walls. Such investigations should ideally be performed in the right context, i.e. in people's homes as socio-acoustic surveys, but when the purpose is to investigate differences in annoyance from different stimuli, it is believed that the results found under controlled experimental conditions are representative for "real life" results. Online tests seem especially attractive for more reasons, and a feasibility study was performed on sound insulation of walls [2]. Noise annoyance measured under experimental conditions is called the annoyance potential of the

stimuli. Noise annoyance can be quantified by different means. In this investigation the self-declared noise annoyance on the ISO/TS 15666 [3] annoyance scale is used. The main purpose of the reported project was to test an online test methodology, but interesting results were found as well.

2. Test methodology and procedures

The sound samples representing four neighbour noises heard through the six different walls were prepared for presentation to the assessors. The sound insulation of the walls was simulated by equalizing the four neighbour noises in order to implement the frequency dependent attenuation curves for the sound insulation of the 6 types of walls selected. The samples - each of a duration of 20 seconds - were calibrated so that the levels were as intended relative to each other. The final 24 sound files representing combinations of sounds and walls were uploaded to SenseLabOnline which arranged the files in a random order for each assessor.

People from the COST TU0901 Action [1] were invited by e-mail to participate in an online listening test. 22 persons from 11 countries completed the test within 2 days. Each assessor

was instructed to make the test in a silent room in their office or at home.

The equipment needed was a computer with sound card, an internet connection and a good pair of headphones. The type of headphones used was not specified. It should be noted that especially for non-open headphones the low frequency reproduction may vary considerably.

In order to simulate the context of the occurrence of neighbour noise, the participants were instructed as follows:

“Close your eyes and concentrate on imagining that you are sitting and relaxing at home and hear the sounds from your neighbours. Imagine that the sounds will appear approximately every 10 minutes with the same duration as in this test”.

The participants had no prior knowledge about the test signals. The total duration of the listening test was estimated to approximately 30 minutes.

The SenseLabOnline internet based listening test software from DELTA [4] was used for the tests.

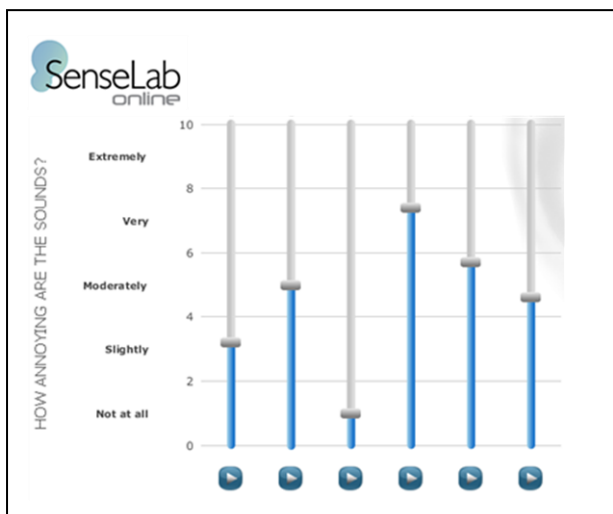


Figure 1. The user interface for the assessors in the SenseLabOnline test on annoyance potential

The sliders shown in Figure 1 are used for the assessment of the stimuli. Below the sliders are play buttons for one of the samples (sounds) heard through the 6 simulated walls in random order. When you click at a new play button there is a soft crossover to the new sound within 40 ms. The labels on the scale are in accordance with ISO/TS 15666. The assessor is allowed to switch forth and back at will between any of the sounds under test. The 4 sounds are presented on one screen each and the order is random for each assessor.

SenseLabOnline provide a feature that allows assessors to focus by zooming in on and looping a part of the sound sample, which is found most relevant.

3. Level calibration

Each assessor started the listening test by adjusting the play-back volume of an audio reference file with male speech, so the voice had a natural volume of a man talking at 1 m distance.

In order to find out which average volume to expect, 24 other persons were asked to make the same adjustment procedure. This experiment involved 6 women and 18 men, aged between 26 and 62 years, (DELTA employees - approximately half of them acousticians). For this experiment a pair of Sennheiser HD 555 headphones was used. The level adjustments were made with a calibrated attenuator and after each trial the setting was noted. In Table 1 the results (measured with the headphones placed on a calibrated artificial head, B&K 4100 Head and Torso Simulator) are shown.

Table I. Mean values, standard deviation and 95 % confidence intervals (CI) for the level adjustment of male speech at 1 m distance made by 24 persons.

	L_{Aeq} , dB
Mean	63.9
Stand. Dev.	4.5
CI 95 %	1.8
Maximal difference	15.0

With a sound level meter, the voice of a male talking in 1 meter distance was measured to $L_{Aeq} = 60$ dB. As seen from Table I the reference audio file was in average adjusted to 64 dB (i.e. 4 dB higher than the natural sound level).

4. Stimuli

4.1 Neighbour noise

The test scheme included evaluation of 6 different walls for 4 types of sounds: Music, people talking (voices), party sounds (people talking, laughing and music) and a toilet flush. The music had bass and heavy drums. The bass drum had the main components at 65 and 130 Hz, and at 50 Hz the level had dropped 6 dB with a steep slope down to lower frequencies. This means that the energy in the frequency bands below 50 Hz is inferior.

The natural levels of the sound samples on sending side were for a start adjusted to the levels indicated in the table below (Table II).

Table II. The natural A-weighted sound pressure levels and the average levels presumably used in the test (estimated test levels) of the sound samples on the sending side of the walls.

Type of sound	Natural level		Estimated test level	
	L_{Aeq} , dB	$L_{Amax,F}$, dB	L_{Aeq} , dB	$L_{Amax,F}$, dB
Flush	69	79	83	93
Music	85	91	99	105
Party	80	86	94	100
Voices	65	74	79	88
Reference speech	60	69	64	73

Taking into account the low volume of the sounds after the attenuation through the walls, two alternative strategies were considered:

1. Play-back at natural levels: Realistic assessments of annoyance potential may be obtained, but some sound samples would be inaudible on the receiving side of the walls.
2. Play-back at increased levels: Unrealistic high annoyance potentials but probably a good relative discrimination among the six walls.

The last option was chosen with an intended level increase of 10 dB. As the mean level of the reference speech probably is adjusted 4 dB higher than assumed this means that the levels of the stimuli was in average 14 dB higher than the natural level.

4.2 Simulated walls

The neighbour noise sounds were processed in order to simulate their transmission through 6 different walls, see Table III.

In Figure 2 the apparent sound reduction index for the 6 walls are presented as function of the frequency.

For wall 1 and 5 the sound insulation field data was taken from reference [5]. The data for other solutions came from the Bastian database [6] (R_w -values). In order to take account for flanking sound transmission, 4 dB were subtracted in the attenuation curves of the walls 2, 3, 4, and for the double heavy wall (wall 6) 8 dB were subtracted. In the frequency range between 5000 Hz to 20000 Hz the sound insulation curves were simulated by an increasing attenuation by 6 dB/octave. For wall 1 (single concrete) the sound insulation data started at 100 Hz, so below this frequency (until 50 Hz) the frequency range was extended by using the mass law (6 dB/octave).

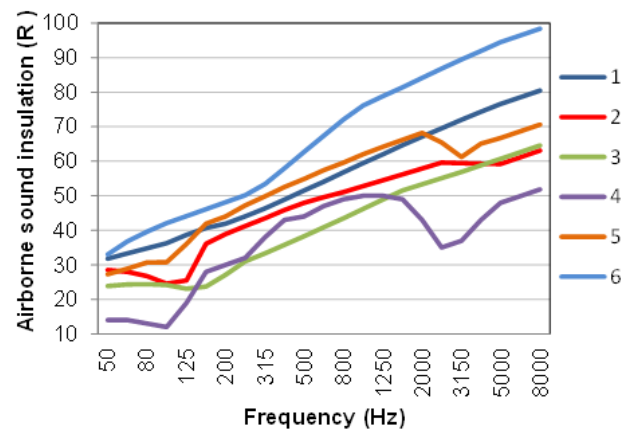


Figure 2. Apparent sound reduction index for the 6 walls (systems). The numbers in the symbols indicate the simulated wall construction, see Table III.

Table III. The walls simulated in the test and their weighted apparent sound reduction index (R'_w).

System no.	Name/code	Details	R'_w , dB
1	Single concrete	200 mm concrete, 2400 kg/m ³	56
2	Single lightweight concrete	260 mm lightweight, concrete 1400 kg/m ³	50
3	Single brick	115 mm brick, 1200 kg/m ³ , render 2 x 10 mm	41
4	Single gypsum	2 x 1 layer of gypsum board, single frame, 45 mm mineral wool	40
5	Double gypsum	2 x 3 layers of gypsum board, double frame, 190 mm mineral wool	57
6	Double concrete	2 x 80 mm concrete, 2400 kg/m ³ 60 mm space, 50 mm mineral wool	63

The walls were chosen to cover a wide sound insulation performance range from R'_w 40 dB up to more than 60 dB, i.e. more than 20 dB range, to provide an appropriate basis for the statistical analysis to be carried out. Furthermore, the curves were selected to represent different shapes of sound insulation curves.

The feasibility test was made for sound insulation of 6 walls. For further investigations (e.g. for comparison of different sound insulation metrics) it is relevant to include more shapes of sound insulation curves.

In the future, it could be interesting to make listening tests with simulations of typical constructions fulfilling the national sound insulation requirements. As the requirements and descriptors vary considerably in Europe, cf. [7] and [8], several construction types and wide performance ranges must be handled in the listening tests.

In COST Action TU0901 [1], a main goal is to prepare a proposal for a harmonized classification scheme with a number of quality classes corresponding to different levels of subjective evaluation. For this purpose, preparatory listening tests would be of utmost importance, although the challenges are high due to even wider performance ranges than for regulatory requirements, cf. [9].

5. Results

Before the data was processed for the final results of the test, the assessor performance (scale usage), agreement and consistence (of repetitions) were inspected. There were significant effects from the variables: Assessors, Walls and Noise samples. The only insignificant variable is the replication, meaning that the assessor generally can replicate their assessments. The most powerful variables are the Walls and Noise samples followed by the Assessor effect.

5.1 Annoyance ratings of the stimuli

Figure 3 shows the annoyance ratings as function of the A-weighted sound pressure levels on the receiving side of the wall.

It is seen that there is a very high correlation between the A-weighted levels and the annoyance even if the spectra of the sound samples differ. A slightly higher correlation is obtained between the annoyance ratings and the loudness levels of the stimuli (not shown).

Figure 4 shows the annoyance scores for each of the sounds heard through each of the walls as function of the R'_w -values. It is seen that the loudest sounds (see Table II) have the highest annoyance potential and that within the confidence intervals the same ranking of the walls is obtained independent of the sound samples.

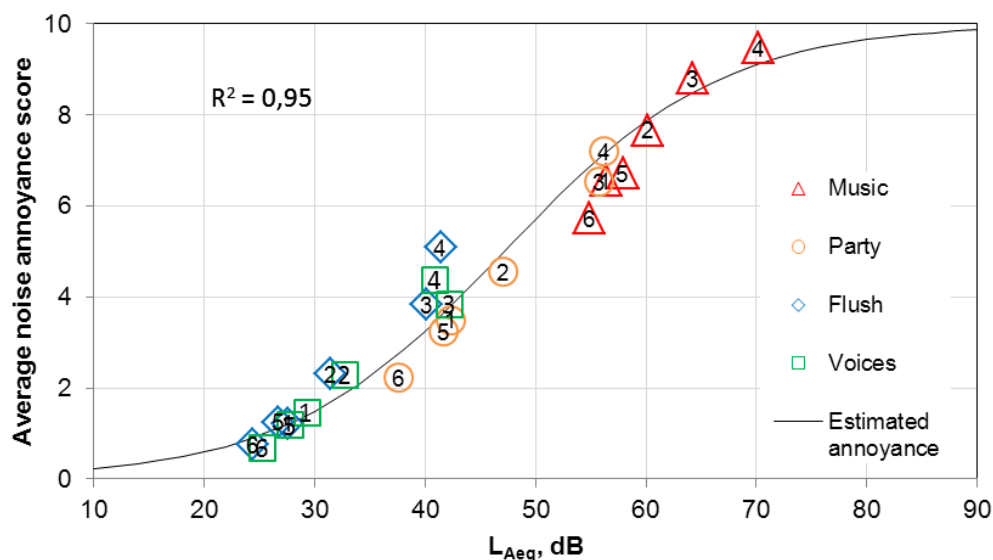


Figure 3. L_{Aeq} - Annoyance. The L_{Aeq} -levels refer to the receiver side of the wall, the y-axis is the average annoyance score on the scales shown in Figure 1. The parameters for the estimated annoyance potential are: $s = 0.1016$, $f = 47.2$ dB - see reference [10]. The numbers in the symbols indicate the simulated wall construction, see Table III.

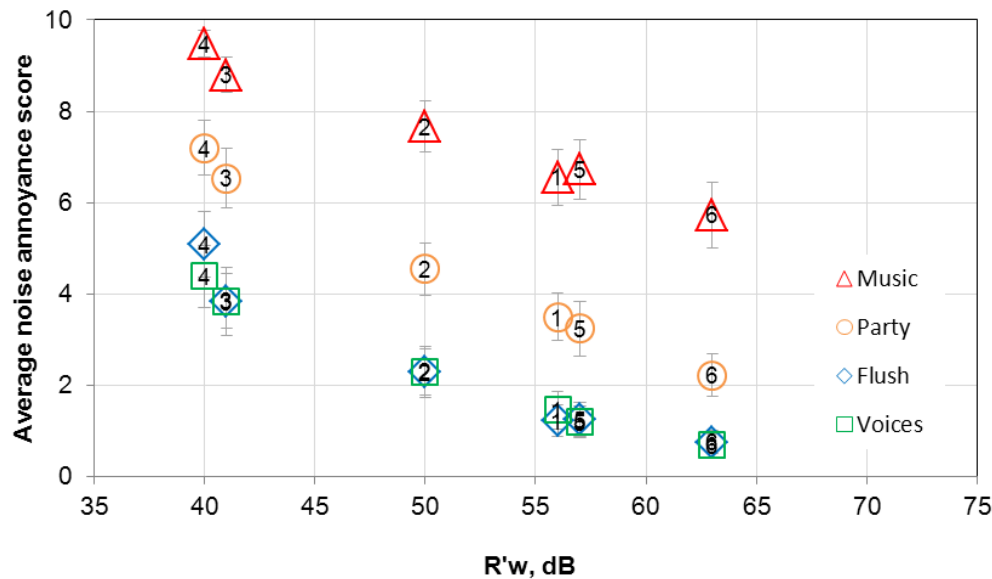


Figure 4. The measured annoyance response averaged over the assessors' responses for each of the four neighbour noises played back approximately 14 dB to loud. The vertical bars is the 95 % confidence intervals. The numbers in the symbols indicate the simulated wall construction, see Table III.

5.2 Annoyance ratings of the walls

Figure 5 shows the relation between the annoyance scores and the R'_w -values for the 6 simulated walls. It is seen that there is a very good relation ($R^2 = 0.98$ by a logistic regression - see reference [10] between the annoyance scores (red dots) and R'_w . The estimated annoyance potential as function

of R'_w averaged over the 4 sounds (toilet flush, music, party and voice sounds) at natural levels is shown with the green line in the figure. This result is found from the L_{Aeq} -Annoyance graph, Figure 3, by decreasing the levels by 14 dB and reading the resulting annoyance potential.

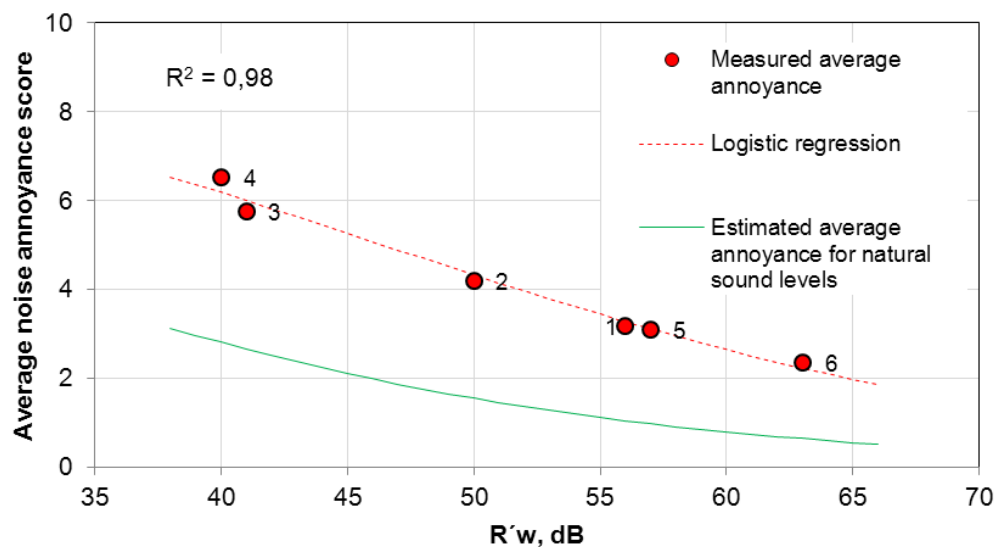


Figure 5. The red dots indicate the measured annoyance averaged over the assessors' responses and the four different stimuli played back approximately 14 dB to loud. The green line indicates the estimated annoyance averaged over the four stimuli at natural level. The parameters for the green curve are: $s = -0.0753$, $f = 27.5$ dB - see reference [10]. The numbers in the symbols indicate the wall construction, see Table III.

6. Conclusions

The main purpose of the study was to investigate the feasibility of the online methodology for listening tests within building acoustics. The tests were performed without any big obstacles, and there is high potential for further development of the methodology and related procedures.

Conclusions, useful experiences and observations concerning different details and aspects of the procedure are found below.

The SenseLabOnline test

A SenseLabOnline [4] test was made on rating the annoyance potential of neighbours' activities heard through different simulated walls. This type of application presents new challenges for listening test, mainly related with the large level range of sounds that could be present in a session. Some of the soft sounds may not be audible, if high insulation values are present. A careful selection of the sound samples should be made. The SenseLabOnline test made it possible to perform a test with 22 assessors from 11 countries in two days.

A simple adjustment procedure for approximate level calibration

No accurate level calibration was made, but the approximate level adjustment procedure seemed to be sufficient for this test. With only approximate calibrated levels at the listener and no conditions about the user's headphones, the overall results of this listening test seem very realistic. The confidence and value of the results will be improved though, with a proper calibration of the levels and the headphones.

A dose-response curve for neighbour noise

The annoyance potentials of 24 samples (4 sound samples heard through 6 wall types) were assessed. This made it possible to find a dose-response curve for the annoyance potential of neighbour noise heard on the receiving side of the walls under experimental conditions.

Relations between the average annoyance potential and R'_w

The sound samples were played back at average supposed levels that were 14 dB higher than the natural levels and that made it possible to achieve results for walls with both high and low R'_w -values. By the help of the dose-response curves (see above) it was possible to find the estimated annoyance potential for different R'_w -values for the sounds at natural levels.

Altogether, based on the feasibility test with four stimuli and six walls, the online test methodology seems very promising for subjective evaluation of airborne sound insulation of walls. In a European perspective, an interesting feature is the possibility to use assessors spread geographically in Europe.

Next steps could be – when funding is available – to refine procedure and perform listening tests related to:

- More stimuli
- More shapes of sound insulation curves
- Floor constructions
- Impact sound

Furthermore, it is relevant to compare results from online listening tests with those using other methodologies.

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